9 RELIABILITY OF LANDSLIDE ZONING FOR LAND USE PLANNING

9.1 POTENTIAL SOURCES OF ERROR

9.1.1 Description

There are a number of potential sources of error in the zoning process. These include:

- Limitations in the landslide inventory upon which the susceptibility and hazard zoning maps are based.
- Limitations in the stability of temporal series. For example the relationship between the triggering factor (e.g. rainfall) and the frequency of landslides may change if the area is deforested.
- Limitations in the level of detail available of topography, geology, geomorphology, rainfall and other input data.
- Model uncertainty, meaning the limitations of the methods used to relate the inventory, topography, geology, geomorphology and triggering events such as rainfall to predicting landslide susceptibility, hazard and risk.
- Limitations in the skill of the persons carrying out the zoning.

It must be recognised that landslide zoning is not a precise science and the results are only a prediction of performance of the slopes based on the available data. In general, intermediate or advanced level zoning will be less subject to error than preliminary level zoning with each done at a suitable zoning map scale.

9.1.2 Landslide inventories

Cascini *et al.* (2005) conclude that the greatest source of error is limitations in the inventory. They give examples showing gross mismatch of inventory maps for landsliding from the same area of natural slopes prepared by two groups. They point out that the greatest errors occur when inventories rely on air photo interpretation, particularly of small scale photography. These errors are in part due to the subjective nature of aerial photo interpretation but also to vegetation covering the areas to be mapped. Aerial photographic mapping should be supported by surface mapping of selected areas to calibrate the mapping.

Inventories of landsliding of cuts, fills and retaining walls on roads, railways and urban development will seldom be complete. To get a reasonable estimate of the number of slides the zoning will have to make a judgement about the proportion of the slides which have been recorded.

9.1.3 Topographic maps

Good topographic maps are most important input to zoning at intermediate and advanced levels. Topographic maps facilitate the modelling and mapping of landslide zoning boundaries with an appropriate accuracy. For large scale zoning, contours at 2 metre or at most 5 metre intervals will be required. Even then, zoning boundaries should be checked on the ground because the implications for land owners of errors in boundaries can be significant.

9.1.4 Model uncertainty

Model uncertainty is a fact of landslide zoning and none of the methods are particularly accurate. In general terms hazard and risk zoning based on statistical analyses of the input data using intermediate level inputs will give the best accuracy.

Sophisticated methods for assessing the inputs rely on carrying out calculations (for example of the factor of safety of a slope) which have a theoretical attraction and the appearance of being able to produce better accuracy. In reality the parameter uncertainty is large due to limitations in the knowledge of the input data (such as shear strength and pore pressures) and these make it very difficult to achieve any greater accuracy than other modelling methods.

9.2 VALIDATION OF MAPPING

9.2.1 Peer review

For most zoning studies for land use planning there should be a peer reviewer appointed to provide independent assessment of the susceptibility, hazard and risk zoning. The peer reviewer should have a high level of the skills and experience listed in Section 11.2.The peer reviewer should meet with those carrying out the study at the beginning of the study and, depending on the scale of the projects, perhaps after initial mapping and then as the zoning is being

finalised. This process is a basic form of quality control and a form of validation if the peer reviewer has appropriate wide experience.

9.2.2 Formal validation

For more important advanced level mapping projects there can be a process of validation within the study. To do this the landslide inventory is randomly split in two groups: one for analysis and one for validation. The analysis is carried out in part of the study area (model) and tested in another part with different landslides. An alternative approach for advanced mapping projects is for an analysis to be carried out with landslides that have occurred in a certain period whilst validation is performed upon landslides that have occurred in a different period. Validation can also be carried out by this process after the mapping and land use planning scheme has been in place for some time. This is really only practical for high frequency landsliding because of the time frame required to gather performance data.

9.3 POTENTIAL EFFECTS OF CLIMATE CHANGE

There is a developing knowledge of climate change and the effects of this on rainfall and snowfall. It could be anticipated that for example a decreased frequency of high intensity rainfall might reduce the frequency of shallow landslides on steep hill slopes. However the science of prediction of the effects of climate change and the prediction of the frequency of landslides from rainfall is not sufficiently advanced at this time to warrant consideration of climate change when carrying out zoning studies.

Those involved in landslide zoning studies should keep informed of developments which might alter this conclusion.

10 APPLICATION OF LANDSLIDE ZONING FOR LAND USE PLANNING

10.1 GENERAL PRINCIPLES

These guidelines are for landslide susceptibility, hazard and risk zoning. Those who are considering the introduction of land use management controls for landsliding need to decide the type and level of zoning which they require based on the purpose of the zoning. This is detailed in Section 6. They may choose to stage the zoning and implementation of land use controls.

It should be recognised that it is not possible to delineate zoning boundaries accurately with regional and local zoning using small and medium scale zoning maps. This can only be done using local or site-specific zoning and large to detailed scale maps.

It is critical that the local governmental authority or other organization requiring the zoning, clearly and fully define the purpose and nature of any zoning study, understand the existing availability of potential input data, assess the implications for acquisition of new data and then define realistic goals for the zoning study taking into account, timeframes, budgets and resource limitations.

It should be noted that mapping will usually result in lines on a map delineating for example the landslide hazard zones based on contours and geomorphologic boundaries. However, for land use planning and zoning purposes the zone boundaries are often re-drawn to coincide with allotment boundaries for administrative reasons. This may lead to adoption of conservative boundaries and should be avoided where practical.

10.2 TYPICAL DEVELOPMENT CONTROLS APPLIED TO LANDSLIDE ZONING

Examples of the types of development controls which are applied to landslide zoning are:

- If zoning is by susceptibility the controls usually require geotechnical assessment of hazard and risk of the proposed development for zones determined as susceptible to landsliding whilst only minimal requirements (such as adherence to good hillside practice) in areas determined as very low susceptibility or not susceptible.
- If zoning is by hazard and the study has been done at an intermediate or advanced level it should be possible to delineate land use zones where: (a) Hazard is so low that no development controls are necessary; (b) Where some prescriptive controls such as limits to the heights of cuts and fills are necessary; (c) Where detailed geotechnical assessment of the hazard and risk is required before development can be approved and (d) Where the hazard is so high no development is possible.
- Where zoning is by life loss risk and the study has been done at an intermediate or advanced level, it should be possible to delineate land use zones where (a) Life loss risk is so low no development controls are necessary; (b) Where site specific assessment of the risk is required prior to approval of development and (c) Where the risk is so high that no development is possible.